Evaluation of Reflection Crack Resistance of Composite Pavements by Accelerated Pavement Testing

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ABSTRACT

Although various construction methods for avoiding reflection crack of asphalt overlay placed on the deteriorated concrete pavement are being implemented, not enough long-term performance of each method has been verified so far. This paper compared the ordinary asphalt overlay with asphalt overlay with waterproof membrane in terms of reflection crack resistance by accelerated pavement testing.

Accelerated pavement testing was performed on composite pavement of asphalt overlay on top of JCP (Joint Concrete Pavement). The test section was divided by two, in terms of the bonding method between the asphalt and concrete layers, i.e. ordinary tack coating and waterproof membrane. The testing temperature was maintained between 18 ~ 24℃ throughout the test period, and the time of reflection crack occurrence and its propagation were measured. The test result showed that overlay with waterproof membrane performed much better in terms of delaying the reflection cracks.

1. Overview

Recently, various construction methods for increasing reflection crack resistance for asphalt overlay of deteriorated concrete pavement are being suggested. However, their long-term performances have not been verified so far.

Generally, reflection cracks of the asphalt overlay are caused by the movement of concrete pavement. The displacement takes place due to various reasons such as deflection of concrete caused by vehicle load, deformation of the concrete caused by temperature change, etc. The magnitude of deflection depends on the load size, number of wheel passes, temperature change, etc.[1].

This study compared typical asphalt overlay with asphalt overlay with waterproof membrane by accelerated pavement testing to simulate the crack occurrence and its propagation in a short

time period. Additionally, the pavement behavior data measured with APT was analyzed with supplemental Finite Element Analysis.

1.1 Composite pavement with waterproof membrane

Composite pavements are generally used in asphalt overlay of deteriorated concrete pavement or bridge deck. They are used mainly to ensure ride ability of existing concrete surface. Nonetheless, reflection crack is the major problem of the composite pavement. Accordingly, asphalt overlay with waterproof membrane was developed to address this problem. It differs from ordinary overlay of applying tack coat between the asphalt-concrete composite layers in that the bonding between the composite layers is accomplished by applying waterproof layer on the top of rubber waterproof admixture for asphalt after spreading the admixture on the concrete pavement surface.

1.2 Testing

The purpose of APT for this study is to compare the long-term performance of asphalt overlay with waterproof membrane with typical asphalt overlay. The occurrence of reflection crack and its propagation behavior were evaluated by APT in simulated laboratory environment similar to the field condition. The data on crack, strain, vertical behavior of concrete slab were collected through the APT. The longitudinal strain of asphalt pavement at the concrete joint was used to examine if the input values for finite element(FE) analysis and the predicted values were appropriate. For the FE analysis ABAQUS computer program was used. In order to simulate different bonding methods, different thickness and contact pressure of the interlayer were used in the analysis.

2. Accelerated Pavement Testing (APT)

2.1 The APT equipment

Accelerated pavement tester has been used for the evaluation of long-term performance of the pavement in a short time period. It usually tests the long-term performance of innovative pavement materials by applying the traffic loading and environmental loading similar to real situation on the top of full-scale pavement structure. The testing equipment used for this research is HAPT (Hanyang Accelerated Pavement Tester) developed for three years between 2000 and 2003 by Hanyang University as shown in <Figure 1>, and it has been used for the long-term performance evaluation of various innovative pavement materials since its development. The specification of HAPT is summarized in <Table 1>.

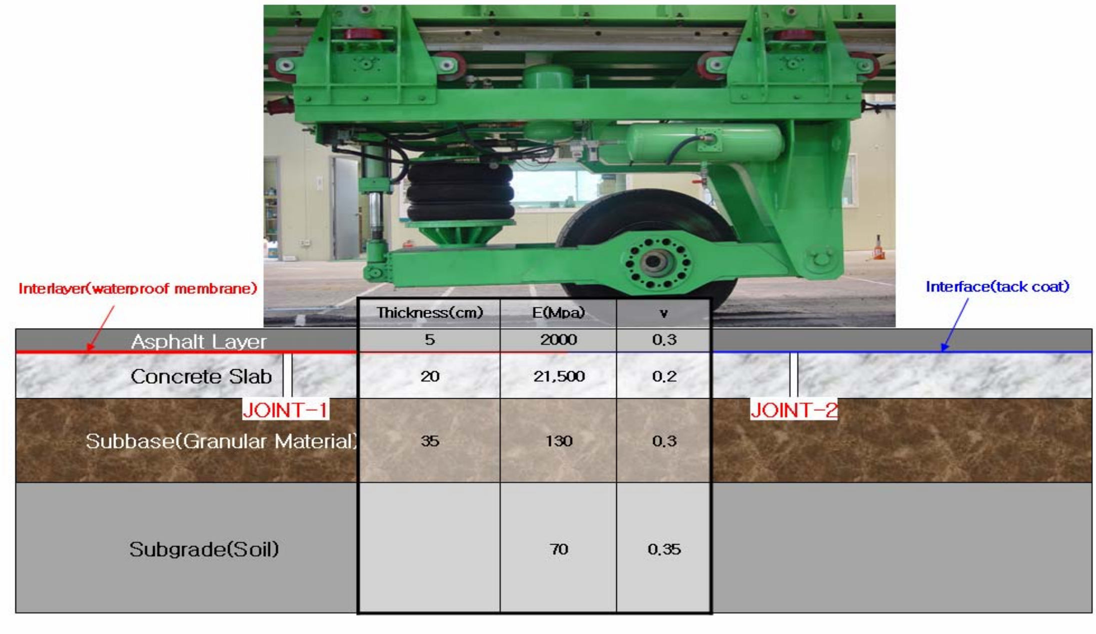
< Figure 1> HAPT (Hanyang Accelerated Pavement Tester)

< Table 1> HAPT characteristics

classification	specification
Loading System	length:20m, width:2m, height:3.4m
Test Section	length:12.5m , width:9.3m, depth:3.2m
Wheel Type	Dual tire
Wheel Loading	3.2 ~ 12ton
Test Speed	Operation speed :8~15km/h Maximum speed:17km/h
Environment Control	Heating System Water table

2.2 Pavement structure

The test was carried out on a test pit consisting of two test sections of ordinary asphalt overlay and asphalt overlay with waterproof membrane. The test pit was 12.5m long and 3.3m wide[2]. The basic pavement structure was same jointed concrete pavement on the same subgrade and subbase for both test sections as shown in <Figure 2>. Cracking was induced by inserting acryl plate into the concrete to simulate the joint before placing the concrete. The two test sections were divided into the section of applying tack coating and the section of applying waterproof membrane at the interface between asphalt layer and concrete slab.



<Figure 2> Pavement structure used for reflection cracking test

Tack coating was applied on the concrete to increase the bond as illustrated in <Figure 3>. The waterproof membrane interlayer was constructed by applying the bonding admixture of 2.5kg per ㎡ in 2mm thickness and then affixing the specially devised waterproof membrane simultaneously onto the admixture as shown in <Figure 4>.

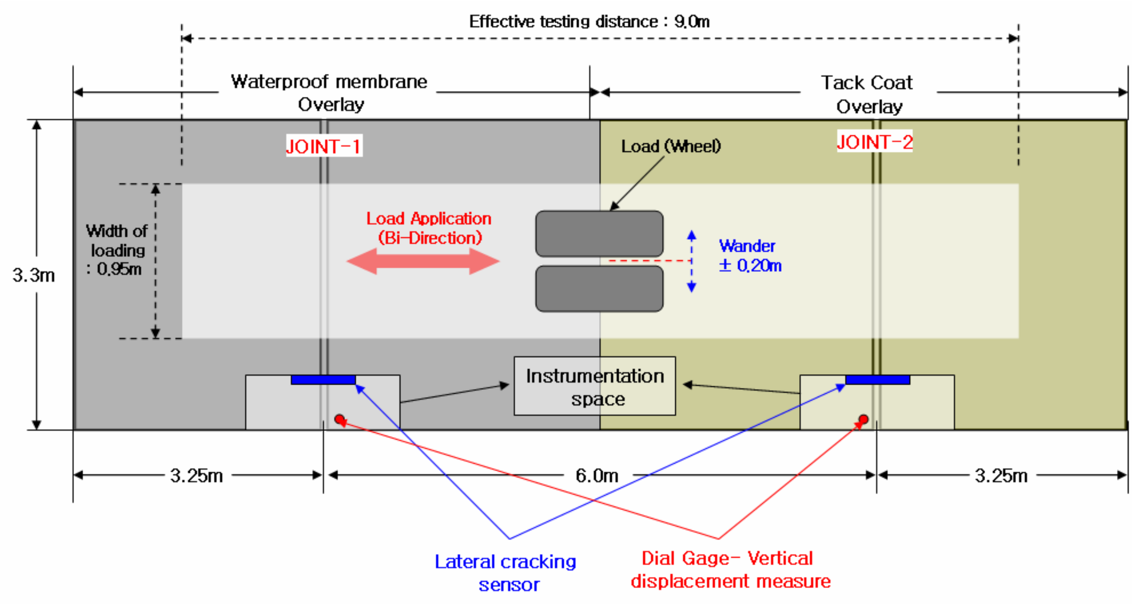
< Figure 3> tack coating

< Figure 4> Asphalt overlay with waterproof membrane

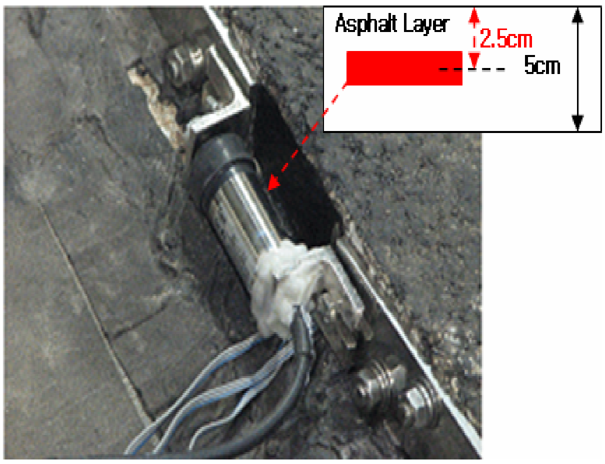
2.3. Instrumentation and trafficking

<Figure 5> shows the instrumentation and trafficking plan of this study. KG-5A gauges and dial gauges were installed as shown in <Figure 6>and <Figure 7> to measure the longitudinal strain and the vertical deflection, respectively.

Visual inspection of cracking was performed to investigate the reflection crack on the asphalt overlay at the joint. Additionally, thermocouples and I-buttons were imbedded in the 2.5 cm depth of asphalt layer and 5 cm and 15 cm depths of concrete slab. The temperature was maintained between 18 ~ 24℃ in order to avoid the influence of permanent deformation on the asphalt layer. Total traffic loadings applied were 150,000 repetitions of 10 ton wheel load with the wandering standard deviation of ±0.2m.



<Figure 5> Locations of Sensor Gauge Installation and effective loading zone



<Figure 6 > Crack Gage

(Lateral strain)

<Figure 7> Dial Gage

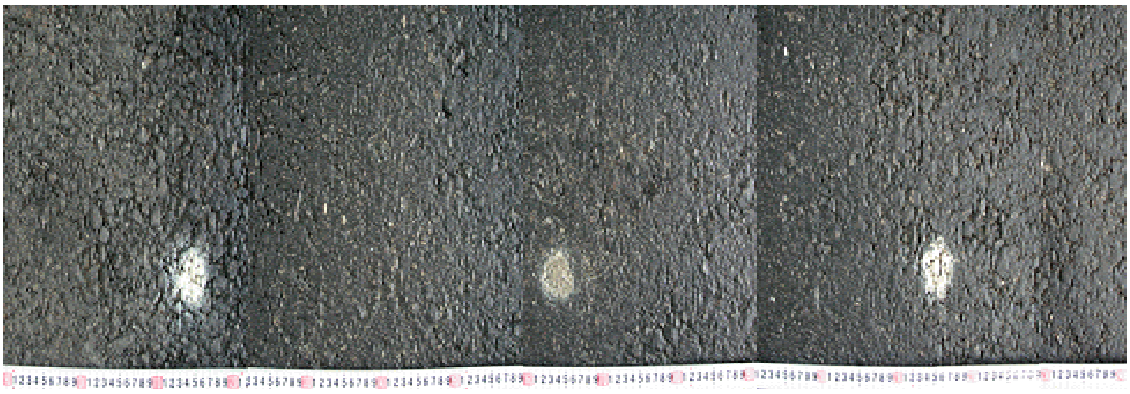
(Vertical Deflection)

2.4. Result of testing

2.4.1. Reflection cracking

Reflection cracks were first observed in the ordinary asphalt overlay section and the waterproof membrane section after 51,800 and 89,440 traffic loadings, respectively. This indicates within the scope of this research that the waterproof membrane overlay method is much more effective in delaying the reflection crack. <Figure 8> through <Figure 13> show the reflection cracking by the number of 10ton loadings for each overlay method, and <Figure

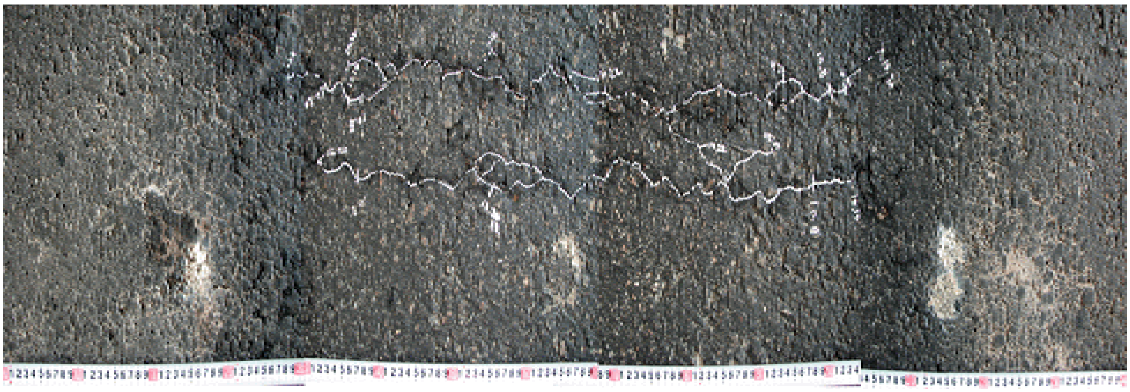
14> illustrates the change in the crack length with the loading. It shows that, ultimately, the length of reflection crack of ordinary overlay method was about 1.83 times greater than that of waterproof membrane overlay method.



<Figure 8> No cracks observed after 69,900 loadings (waterproof membrane section)

<Figure 9> Cracks observed after 69,900 loadings (tack coating section)

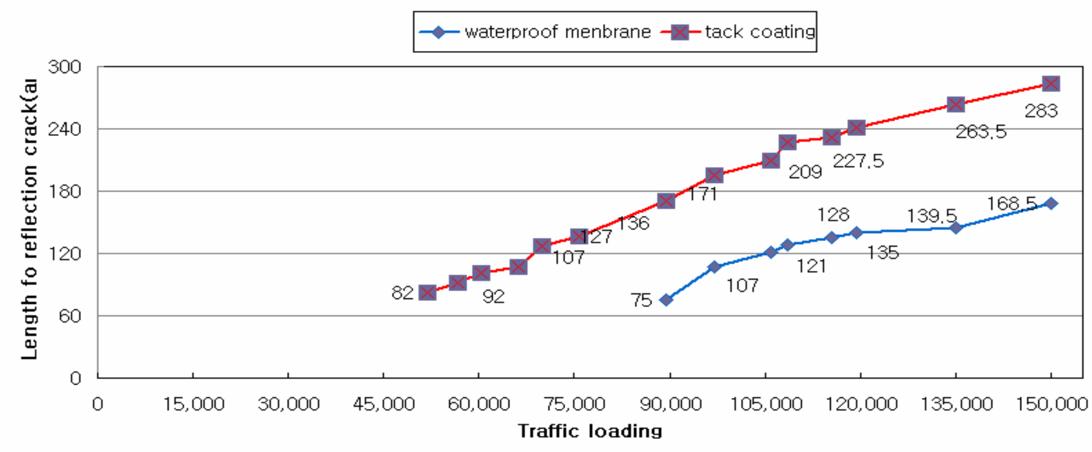
<Figure 10> Cracks observed after 105,940 loadings (waterproof membrane section)



<Figure 11> Cracks observed after 105,940 loadings (tack coating section)

<Figure 12> Cracks observed after 150,000 loadings (waterproof membrane section)

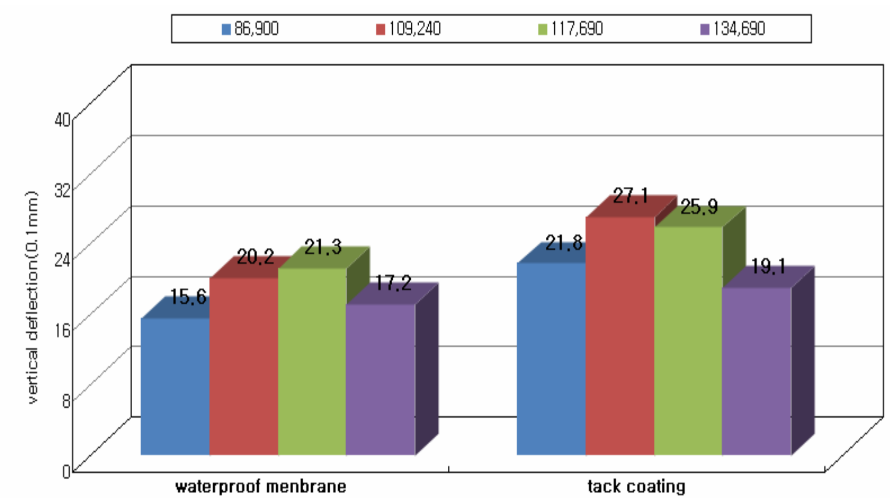
<Figure 13> Cracks observed after 150,000 loadings (tack coating section)



<Figure 14> Length of reflection crack by each overlay method

2.4.2 Vertical deflection of concrete slab

The vertical movement of concrete slab was measured with dial gauge at the location illustrated in <Figure 5>. The result showed that the vertical deflection by load was about 26% lower in the waterproof membrane section as shown in <Figure 15>. This might be because the vertical deflection of concrete slab is indirectly transmitted to the asphalt layer through waterproof membrane.



<Figure 15 > Vertical movement of the concrete slab by each overlay method

3. Finite Element Analysis of APT Result

The crack gauge was installed in the lateral cracking sensor location in <Figure 5 > to measure the strain developed by the loading. Actually the strain basin of the various positions near the loading could be measured except strains occurred right underneath the loading.

These missing values were predicted using FE analysis. The analysis program used was ABAQUS. ABAQUS program is commercial structural analysis software developed by Hibbit, Karlsson & Sorensen Company of the USA with excellent functionality of non-linear finite element analysis. This program is largely grouped into three modules of ABAQUS (Main Solver), POST (After analysis), and PLOT (Output). This study used ABAQUS version 6-4-1.

3.1 Input data of ABAQUS

<Table 2> compares the input data for the two different cases of this study. The poison ratio and modulus of elasticity for each layer and its thickness are the same for both cases. However, the thickness of waterproof membrane of 0.5m was considered in the analysis. The elastic modulus and the contact pressure of the waterproof membrane are predicted from the analysis as shown in <Table 2>.

<Table 2> Input Data of ABAQUS

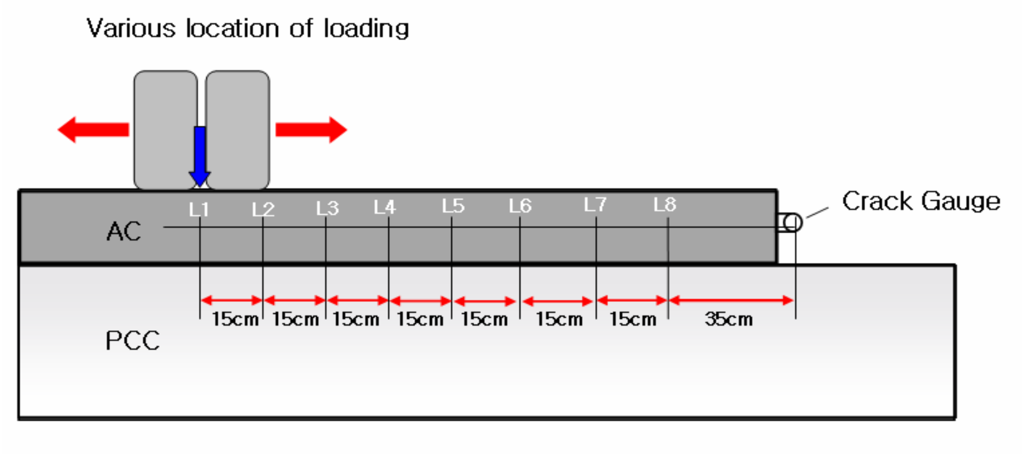
Input Values		Overlay with waterproof membrane	Overlay with tack coating
Asphalt Layer	Thickness(cm)	5	
	E(Mpa)	2000	
	v	0.3	
Concrete Slab	Thickness(cm)	20	
	E(Mpa)	21500(Comp. Strength 21Mpa)	
	v	0.2	
Subbase	Thickness(cm)	35	
	E(Mpa)	130	
	v	0.3	
Interlayer (best fit values)	Thickness	0.5cm	-
	E(Mpa)	2.5	-
	Contact Pressure	0.7 Mpa	1.0 Mpa

3.2 Analysis condition and the results

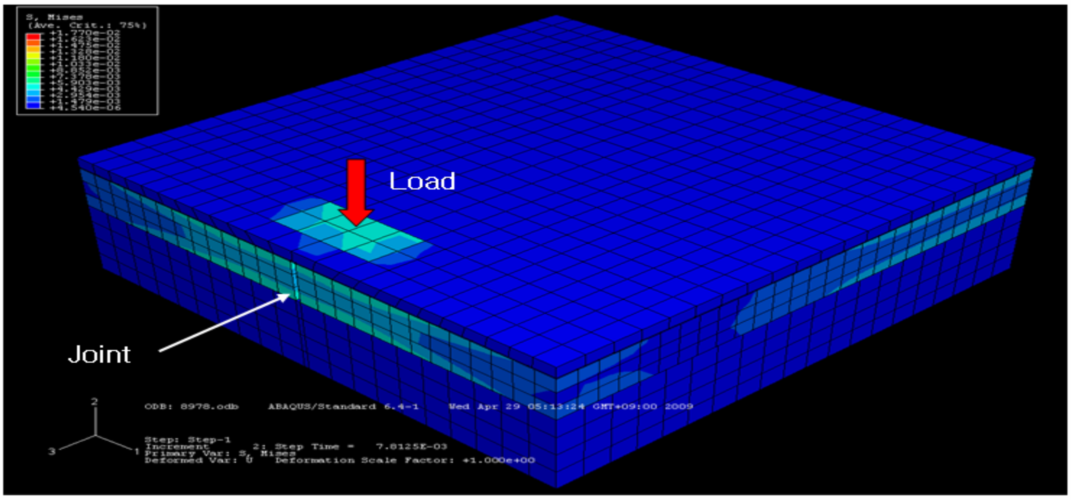
3.2.1 Traffic loadings

The location of loading was varied to obtain the tensile strain profile of the asphalt layer along the horizontal plane while the location of gauges remained fixed as depicted in <Figure 16>.. The input loading for ABAQUS was set to be a rectangular dual tire of 0.4m × 0.2m size, and its

tire pressure was set at 0.612Mpa.



<Figure 16> Measurement of the horizontal tensile strain of the asphalt layer with respect to loading location by APT



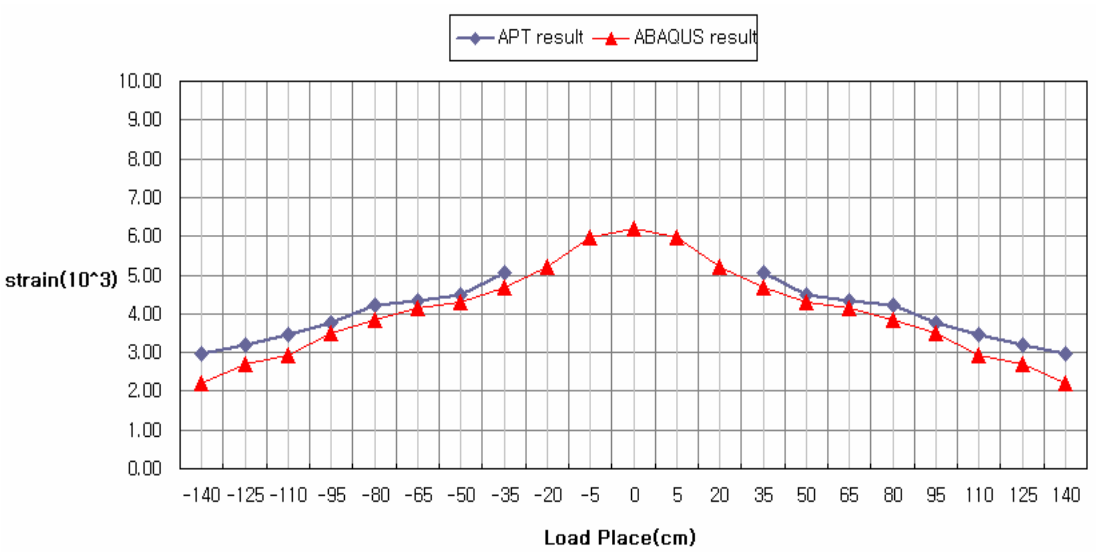
<Figure 17> ABAQUS simulation of loading

3.2.2 Comparison of measured longitudinal strain with predicted longitudinal strain

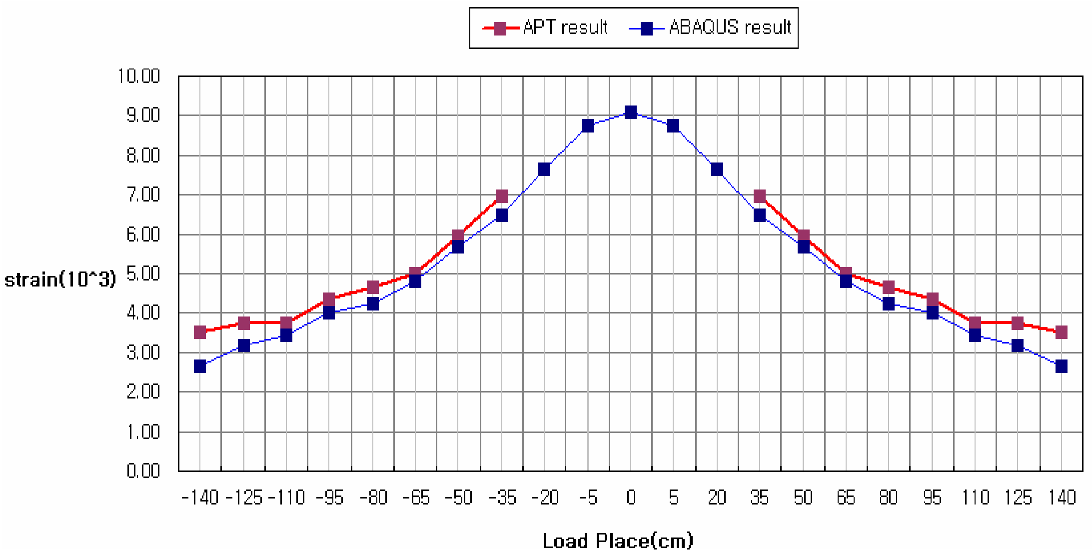
Since the strain at the center loading (0 ~ 35cm from the center of the loading) could not be measured in this study as shown in <Figure 16>, <Figure 18>, and <Figure 19>, the missing strain data were predicted using ABAQUS analysis. The strain distribution predicted by ABAQUS was compared with the measured strains from the gauge instruments, and the best fit stain distribution was selected for the prediction of the missing data as shown in <Figure 18> and <Figure 19>. The result indicated that the input of 0.5cm thickness, 0.7MPa contact

pressure at the interface layer, and 2.5Mpa modulus of elasticity exhibited the closest pattern to the measured value for the case of overlay method of using waterproof membrane. The case of ordinary overlay used the input variable of contact pressure only since the thickness of tack coating is meaningless, and it showed the closest behavior to the measured value with the contact pressure value of 1.0Mpa. The difference between the actual measured values and predicted values of horizontal strain of the asphalt layer with respect to the loading location was 7.8% on the average.

It was found from <Figure 18> and <Figure 19> that the waterproof membrane section showed much less maximum strain than the ordinary overlay section. This is construed due to the flexible waterproof membrane of 0.5 cm thickness, which alleviated the movement to the asphalt overlay. The same conclusion was made from the result of FE analysis. It was indicated from both results of APT and FE analysis that the waterproof membrane interlayer reduced the strain of the asphalt layer.



<Figure 18> Comparison of measured longitudinal strain with predicted longitudinal strain (waterproof membrane section)



<Figure 19> Comparison of measured longitudinal strain with predicted longitudinal strain (ordinary overlay section)

4. Conclusions

This study evaluated the asphalt overlay with waterproof membrane interlayer on a jointed concrete pavement in terms of reflection cracking using Accelerated Pavement Testing (APT). Additionally, ABAQUS computer program was used to predict the pavement behavior in response to traffic loading. The following conclusions are derived within the scope of this study.

(1) Reflection cracking was first observed in the ordinary asphalt overlay section (tack coating only at the interface) and comparative asphalt overlay test section (waterproof membrane as the interlayer) after 51,800-times and 89,440-times loadings, respectively. This indicates that the asphalt overlay using waterproof membrane is more effective in delaying reflection cracking compared to the ordinary asphalt overlay method of using tack.

(2) Vertical deflection by load was about 26% lower in the waterproof membrane section. This might be because the vertical deflection of concrete slab is indirectly transmitted to the asphalt layer through waterproof membrane.

(3) Waterproof membrane section showed much less tensile strain by load than the ordinary overlay section. This is construed because the flexible waterproof membrane of 0.5 cm thickness alleviated the movement to the asphalt overlay.

(4) Both results of APT measurement and FE analysis indicated that the waterproof membrane interlayer reduced the deflection of the concrete joint and at the same time decreased the strain of the asphalt layer.

(5) Additional Finite Element Analysis is planned for the extension of this study on the reflection crack occurrence and its propagation in the pavement as a future research. This investigation will enable additional analysis of the pavement cracking by fracture mechanism and comprehensive analysis of the reflection crack occurrence and its propagation in the pavement.

References

1. S. A. Perez., J. M. Balay. (2007), "Accelerated Pavement Testing and Modeling of Reflective Cracking in Pavements", www.elsevier.com/localte/engfailanal.
2. Sung-Ho, Bae. (2003), "Accelerated Pavement Testing for the Evaluation of Long Term Pavement Performance", Master's thesis, Hanyang University.